

## Ultrasonic Studies In The Binary Mixtures Of Dimethyl Carbonate With Some Aliphatic Esters

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### Abstract

The binary mixes Di Methyl Carbonate (DMC) + Methyl Acetate (MA), + Ethyl Acetate (EA), and + Butyl Acetate (BA) were measured for ultrasonic velocity ( $U$ ), density ( $\rho$ ), and viscosity ( $\eta$ ) at four different temperatures (303.15-318.15K) covering the whole composition range. Deviations in adiabatic compressibility and viscosity, as well as excess values of molar volume, intermolecular free length, and relaxation time, were computed from the experimental data. To find binary constants and the standard deviation ( $\sigma$ ) between the estimated and experimental values, the Redlich-Kister polynomial equation has been fitted to the values of  $V^E$ ,  $\Delta\beta_{ad}$ ,  $L_f^E$ ,  $\Delta\eta$ .

**Keywords:** Di methyl carbonate, Densities, Speed of sound, Viscosity Compressibilities, Molar volumes, Inter Molecular Free Lengths.

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### I. Introduction

In the majority of engineering computations, where fluid flow or mixing plays a significant role in numerous real-world issues pertaining to mass transport applications, the physical characteristics of liquid mixes are necessary. DMC has a dipole moment of 0.90 D and is a polar, aprotic solvent. DMC is primarily utilized as an intermediate in the synthesis of different polymers and in the electrolytes of lithium-ion batteries, which are anticipated to be crucial for energy storage, as well as in the manufacturing of biodiesel and building materials like paints and cleaning and degreasing agents. On the other side, esters are used as plasticizers in the polymer processing industry to promote thermoplastic behaviour [1-3]. It is crucial to comprehend how DMC mixes with esters because this knowledge may be useful in a variety of engineering fields. At 303.15, 308.15, and 313.15 K, we present the density, viscosity, and sound speed findings for the binary mixes of DMC with methyl acetate, ethyl acetate, n-butyl acetate, and n-butyl acetate across the whole composition range. This information has been used to calculate the excess molar volume, viscosity deviations, sound speed deviations, adiabatic compressibility deviation, acoustic impedance, and excess Gibbs free energy of activation of viscous flow. To determine the binary coefficients and standard deviation, these findings were fitted to the Redlich-Kister polynomial equation using a multiparametric nonlinear regression analysis technique.

### II. Experimental Techniques

#### a) Measurement of Velocity

The formula  $U=\lambda f$  can be used to calculate the ultrasonic velocity. The frequency of the generator employed in the investigation is 2 MHz. To get the high frequency generator's anode current meter to read its maximum, a micrometer screw and a lot of work were required. While adjusting the micrometer screw for n peaks, we should note how many times the anode current was at its highest.

$$d = n\lambda/2$$

Multiplying the displacement of the reflector by 20 peaks by 100 makes it easy to determine the speed in meters per second. Since the distance 'd' can be determined with a micrometer to an accuracy of 0.01 mm or more, the quality of the distance measurement largely determines the velocity's precision.

#### b) Measurements of Density

In the current investigation, a specific gravity bottle with a 5ml volume was used to test the density ( $\rho$ ) for pure liquids and all liquid combinations at various temperatures between 303.15K and 318.15K with a 5K interval. One of the factors utilized to assess the liquids' purity was their density. To achieve thermal equilibrium, the specific gravity bottle was placed in the thermostat for fifteen minutes. When they reach room temperature, they are taken out of the thermostat and weighed. There is a 0.5 mg margin of error in the density readings.

### c) Measurements of Viscosity

At 303.15, 308.15, 313.15, and 318.15K, the viscosity was measured using a 0.55mm diameter Ubbelohde capillary viscometer that was calibrated using double-distilled water. The viscometer is calibrated using pure water, and the liquid is allowed to stand in a thermostatic water bath for about half an hour to minimize temperature swings. The precision of the viscosity measurements is 0.005 mPas.

### III. Theoretical Considerations

i) Molar volume

$$V = M / \rho \quad 3.1$$

ii). Excess Volume ( $V^E$ )

$$V^E = V - (V_1 X_1 + V_2 X_2) \quad 3.2$$

where  $X_1$  indicates the mole fractions of common compound and  $X_2$  indicates the molefraction of sub compound and  $V_1$  &  $V_2$  are the mean molar volumes respectively.

iii). Adiabatic Compressibility ( $\beta_{ad}$ )

$$\beta_{ad} = 1 / \rho U^2 \quad 3.3$$

iv). Deviation in Adiabatic compressibility ( $\Delta\beta_{ad}$ )

$$\Delta\beta_{ad} = \beta_{ad} - (\beta_{ad1} X_1 + \beta_{ad2} X_2) \quad 3.4$$

where pure liquids' adiabatic compressibilities are indicated as  $\beta_{ad1}$  and  $\beta_{ad2}$ .

v). Intermolecular free length ( $L_f$ )

$$L_f = K (\beta_{ad})^{1/2} \quad 3.5$$

Jacobson constant is indicated as K.

vi). Excess Intermolecular free length ( $L_f^E$ )

$$L_f^E = L_f - (L_{f1} X_1 + L_{f2} X_2) \quad 3.6$$

pure liquids' intermolecular free length are  $L_{f1}$  and  $L_{f2}$  respectively

vii). Deviation in Viscosity ( $\Delta\eta$ )

The equation for deviation in viscosity is

$$\Delta\eta = \eta_{mix} - (X_1 \eta_1 + X_2 \eta_2) \quad 3.7$$

The liquid mixture and the pure liquids' viscosities are indicated as  $\eta_{mix}$ ,  $\eta_1$  and  $\eta_2$  are respectively.

The excess/deviation values of  $\Delta\beta_{ad}$ ,  $V^E$ ,  $\Delta\eta$ ,  $L_f^E$ , were least squares fitted to the Redlich – Kister type polynomial<sup>4</sup>

$$Y^E = X(1-X) \sum_{i=1}^n A_i (1-2X)^{i-1} \quad 3.8$$

The coefficients of  $A_i$  in the above equation along with the standard deviation ( $Y^E$ ) are given in Tables. These coefficients are the adjustable parameters to get best - fit values of  $Y^E$  which are indicated in the table along with standard deviations ( $Y^E$ ) calculated by using the following relation

$$\sigma Y^E = \sum \left[ \frac{[Y_{exp}^E - Y_{cal}^E]^2}{m - n} \right]^{1/2} \quad 3.9$$

### Theoretical Velocities

Nomoto [5] developed the following ratio for liquid mixes assuming the additivity of molar sound velocity (R) and no volume change upon mixing

$$U_N = \left[ \frac{X_1 R_1 + X_2 R_2}{X_1 V_1 + X_2 V_2} \right]^3 \quad 3.10$$

According to Blandamer and Waddington's [6] assumptions, the ideal mixing theory put forth by Van Dael and Vangeel [7] yields the following relation for ultrasonic velocity in liquid mixtures:

$$\frac{1}{[X_1 M_1 + X_2 M_2] [U_{mix}]^2} = \frac{X_1}{M_1 U_1^2} + \frac{X_2}{M_2 U_2^2} \quad 3.11$$

where  $U_{\text{imx}}$  is the liquid mixture's optimal ultrasonic mixing velocity. Ultrasonic velocity in species is represented by  $U_1$  and  $U_2$ .

#### Impedance Relation

Using the specific acoustic impedance of the pure liquids, the ultrasonic speed in the liquid mixtures is determined using the following relation [8]

$$U_{\text{Imp}} = \frac{\sum X_i Z_i}{\sum X_i \rho_i} \quad 3.12$$

Where  $X_i$  is the molefraction,  $Z_i$  acoustic impedance and  $\rho_i$  is the density

Using the ratio of the temperature coefficient of speed and expansion coefficient, Rao[9] derived a formula for ultrasonic speed ( $U_R$ ) given by

$$U_R = \left[ \frac{R}{V} \right]^3 \quad 3.13$$

where  $V$  is the molar volume and  $R$  is called Rao's constant or molar sound speed, which is constant for a liquid at a temperature. Junjie [10] assumed that the ultrasonic speed of the mixture depends on the mole fraction, molecular weight and density of the mixture. Junjie's relation is given by

$$U_j = \frac{\left[ \frac{X_1 M_1}{\rho_1} + \frac{X_2 M_2}{\rho_2} \right]}{\left[ X_1 M_1 + X_2 M_2 \right]^{1/2} \left[ \frac{X_1 M_1}{\rho_1 U_1^2} + \frac{X_2 M_2}{\rho_2 U_2^2} \right]^{1/2}} \quad 3.14$$

#### ix Chi-square test for goodness of fit

As indicated by Karl Pearson [11], Chi-square value is evaluated for the binary liquid mixtures under study utilizing the formula

$$\chi^2 = \frac{\left[ U_{\text{obs}} - U_{\text{Cal}} \right]^2}{U_{\text{Cal}}} \quad 3.15$$

where  $n$  is the number of data used, and  $U$  (obs) = experimental values of ultrasonic velocities  $U$ (cal) = computed values of ultrasonic velocities

#### x Relative Percentage Error

The Average percentage error is calculated by utilizing the relation

$$\text{APE} = \frac{1}{n} \sum \left[ \frac{U_{\text{obs}} - U_{\text{cal}}}{U_{\text{obs}}} \right] \times 100 \quad 3.16$$

#### xi Molecular Association

The degree of intermolecular interaction or molecular association is given by

$$\alpha = \frac{U_{\text{exp}}^2}{U_{\text{imx}}^2} - 1 \quad 3.17$$

### IV. Solvent Purification

Because the purity of the liquid affects the accuracy and precision of the results, it is imperative to utilize the purest components available. When creating several purification methods, which are detailed in the literature, the type and functional groups of the compounds were taken into account [12,13].

**Table-1: Literature Data in comparison with experimental data at 303.15K**

| Liquid | Density( $\rho$ ) Kg/m <sup>3</sup> |                       | Velocity of Ultrasonic Sound( $U$ )m/s |                      | Viscosity( $\eta$ ) cP |                      |
|--------|-------------------------------------|-----------------------|----------------------------------------|----------------------|------------------------|----------------------|
|        | Exptl                               | Lit                   | Exptl                                  | Lit                  | Exptl                  | Lit                  |
| DMC    | 1.0562                              | 1.05671 <sup>14</sup> | 1175.3                                 | 1177 <sup>14</sup>   | 0.549                  | 0.549 <sup>14</sup>  |
| MA     | 0.9206                              | 0.9201 <sup>15</sup>  | 1106                                   | 1106.5 <sup>15</sup> | 0.372                  | 0.3514 <sup>15</sup> |

|    |        |                      |        |                      |       |                      |
|----|--------|----------------------|--------|----------------------|-------|----------------------|
| EA | 0.8885 | 0.8884 <sup>15</sup> | 1117.3 | 1122.8 <sup>15</sup> | 0.382 | 0.3995 <sup>15</sup> |
| BA | 0.8716 | 0.8712 <sup>15</sup> | 1165.2 | 1176.4 <sup>15</sup> | 0.643 | 0.6407 <sup>15</sup> |

## V. Results & Discussion

Tables 2, summarize excess characteristics of DMC with methyl, ethyl, and n-butyl acetate calculated by using the values of density, ultrasonic velocity, viscosity, and at temperatures ranging from 303.15 to 318.15K. Table 3 shows the values of parameters  $A_0$ ,  $A_1$ ,  $A_2$ ,  $A_3$ , and  $A_4$  derived by least squares analysis, along with their standard deviation.

Figs 1(a), 1(b) and 1(c) illustrate the relationship between excess volume ( $V^E$ ) and DMC mole fraction at various temperatures. The main causes of volume expansion, or positive  $V^E$  values, are

- (i) Chemical interactions between constituent molecules, such as the creation of H-bonds.
- (ii) Association through weaker physical forces, such as dipolar force or other similar factors.
- (iii) Molecules from one component are accommodated in the interstitial places of the other's structural network.

The strength of unlike molecular interactions in a solution can be assessed by the sign and magnitude of  $V^E$ .  $V^E$  values are negative across all three systems. However, methyl acetate has significantly higher negative  $V^E$  values compared to other esters. The lower size of methyl acetate molecules in the DMC dipole network suggests interstitial accommodation. The negative  $V^E$  values at higher temperatures suggest the interstitial accommodation of methyl acetate molecules [16].

DMC with aliphatic esters have algebraic  $V^E$  values about 303.15K followed the order: MA>EA>BA

Volume expansion is caused by the breaking up of molecular clumps or dipolar molecules, as well as dispersion forces between molecules.

The sign of a system's  $V^E$  is determined by the relative expansion and contraction of the two liquids during mixing. Previous studies reported similar results [17].

The development of hydrogen bonds and dipole-dipole interactions between hetero molecules can significantly impact the system's compressibility. The differences in adiabatic compressibility can be explained by the following reasons.

- a) Differences in size and shape of component molecules reduce velocity and increase compressibility.
- b) Dipole-dipole interaction or hydrogen bonding between molecules leads to increased sound velocity and decreased compressibility.

The actual deviation is determined by the resulting effect. Figures 1(b), 2(b) and 2(c) show negative deviations in adiabatic compressibilities over DMC mole fractions, showing significant interactions between molecules.

$\Delta\beta_{ad}$  values are consistently negative across all compositions and intensify at increasing temperatures. The structure of homologous series of esters has a significant impact on adiabatic compressibility. Figures 1(b), 2(b) and 2(c) show that when the ester chain length decreases, the  $\Delta\beta_{ad}$  values become increasingly negative.

In this investigation, the behavior of  $V^E$  and  $\Delta\beta_{ad}$  are comparable. The sign of  $\Delta\beta_{ad}$  supports the postulates used to understand the excess molar volume sign. Negative  $V^E$  and  $\Delta\beta_{ad}$  values may be caused by dipole-dipole and dipole-induced dipole interactions. [15-18] that improve the solvent structure of the mixture, hence lowering  $V^E$  and  $\Delta\beta_{ad}$ .

**Table 2: Excess/deviation values of calculated thermodynamic parameters for DMC + MA, EA and BA systems at 303.15, 308.15, 313.15 and 318.15K**

| DMC+Methyl Acetate |                    |         |         |                | DMC+Ethyl Acetate |                    |         |         |                | DMC+Butyl Acetate |                    |         |         |                |
|--------------------|--------------------|---------|---------|----------------|-------------------|--------------------|---------|---------|----------------|-------------------|--------------------|---------|---------|----------------|
| $X_1$              | $\Delta\beta_{ad}$ | $V^E$   | $(L^E)$ | $(\Delta\eta)$ | $X_1$             | $\Delta\beta_{ad}$ | $V^E$   | $(L^E)$ | $(\Delta\eta)$ | $X_1$             | $\Delta\beta_{ad}$ | $V^E$   | $(L^E)$ | $(\Delta\eta)$ |
| 303.15K            |                    |         |         |                |                   |                    |         |         |                |                   |                    |         |         |                |
| 0.0000             | 0.0000             | 0.0000  | 0.0000  | 0.0000         | 0.0000            | 0.0000             | 0.0000  | 0.0000  | 0.0000         | 0.0000            | 0.0000             | 0.0000  | 0.0000  | 0.0000         |
| 0.0949             | -4.5347            | -0.2162 | -0.0477 | 0.3050         | 0.1144            | -3.8711            | -0.1754 | -0.0399 | 0.2620         | 0.1479            | -4.6004            | -0.1473 | -0.0499 | 0.4780         |
| 0.1909             | -7.6496            | -0.4521 | -0.0821 | 0.5910         | 0.2252            | -6.5265            | -0.4004 | -0.0687 | 0.5390         | 0.2809            | -7.4888            | -0.3654 | -0.0832 | 0.9440         |
| 0.2879             | -9.7808            | -0.6340 | -0.1070 | 0.7700         | 0.3326            | -8.6687            | -0.5895 | -0.0935 | 0.7030         | 0.4011            | -9.5824            | -0.5533 | -0.1089 | 1.1930         |
| 0.3861             | -11.2247           | -0.7699 | -0.1250 | 0.9180         | 0.4367            | -9.9526            | -0.7270 | -0.1095 | 0.8340         | 0.5102            | -11.0311           | -0.6929 | -0.1278 | 1.3240         |
| 0.4855             | -12.2569           | -0.8458 | -0.1390 | 0.9940         | 0.5376            | -10.8296           | -0.8105 | -0.1216 | 0.8890         | 0.6098            | -11.5313           | -0.7818 | -0.1356 | 1.3220         |
| 0.5860             | -11.5478           | -0.7412 | -0.1324 | 0.8860         | 0.6356            | -10.5332           | -0.6898 | -0.1201 | 0.8520         | 0.7010            | -11.3980           | -0.6689 | -0.1356 | 1.1840         |
| 0.6876             | -9.4760            | -0.6137 | -0.1091 | 0.7690         | 0.7307            | -8.5880            | -0.5637 | -0.0985 | 0.7220         | 0.7848            | -9.6627            | -0.5207 | -0.1154 | 0.9940         |
| 0.7905             | -7.0899            | -0.4755 | -0.0821 | 0.5400         | 0.8230            | -6.4461            | -0.4218 | -0.0744 | 0.4820         | 0.8621            | -7.4704            | -0.3789 | -0.0894 | 0.6790         |
| 0.8946             | -4.3851            | -0.2587 | -0.0511 | 0.2710         | 0.9128            | -3.2247            | -0.2009 | -0.0372 | 0.2260         | 0.9336            | -3.9486            | -0.1668 | -0.0470 | 0.4030         |
| 1.0000             | 0.0000             | 0.0000  | 0.0000  | 0.0000         | 1.0000            | 0.0000             | 0.0000  | 0.0000  | 0.0000         | 1.0000            | 0.0000             | 0.0000  | 0.0000  | 0.0000         |
| 308.15K            |                    |         |         |                |                   |                    |         |         |                |                   |                    |         |         |                |
| 0.0000             | 0.0000             | 0.0000  | 0.0000  | 0.0000         | 0.0000            | 0.0000             | 0.0000  | 0.0000  | 0.0000         | 0.0000            | 0.0000             | 0.0000  | 0.0000  | 0.0000         |
| 0.0949             | -5.0185            | -0.2685 | -0.0528 | 0.2420         | 0.1144            | -4.9962            | -0.2689 | -0.0508 | 0.2190         | 0.1479            | -5.6198            | -0.2277 | -0.0604 | 0.3140         |
| 0.1909             | -7.9970            | -0.5295 | -0.0856 | 0.4730         | 0.2252            | -8.0229            | -0.4865 | -0.0833 | 0.4760         | 0.2809            | -9.4916            | -0.4900 | -0.1048 | 0.7500         |

|         |          |         |         |        |        |          |         |         |        |        |          |         |         |        |
|---------|----------|---------|---------|--------|--------|----------|---------|---------|--------|--------|----------|---------|---------|--------|
| 0.2879  | -10.3259 | -0.6901 | -0.1126 | 0.6500 | 0.3326 | -9.8396  | -0.6830 | -0.1042 | 0.6270 | 0.4011 | -11.5439 | -0.7005 | -0.1301 | 0.9820 |
| 0.3861  | -11.5639 | -0.8131 | -0.1280 | 0.8270 | 0.4367 | -11.3715 | -0.8457 | -0.1230 | 0.7260 | 0.5102 | -13.3871 | -0.8485 | -0.1539 | 1.1220 |
| 0.4855  | -12.6706 | -0.8914 | -0.1426 | 0.8950 | 0.5376 | -12.6148 | -0.9123 | -0.1396 | 0.7810 | 0.6098 | -13.6246 | -0.9118 | -0.1586 | 1.1420 |
| 0.5860  | -12.0016 | -0.7929 | -0.1364 | 0.8060 | 0.6356 | -12.2780 | -0.7926 | -0.1379 | 0.7420 | 0.7010 | -13.7541 | -0.8146 | -0.1622 | 1.0060 |
| 0.6876  | -9.8703  | -0.6804 | -0.1126 | 0.6520 | 0.7307 | -10.4970 | -0.6792 | -0.1189 | 0.6160 | 0.7848 | -12.2357 | -0.6508 | -0.1450 | 0.8490 |
| 0.7905  | -7.7038  | -0.5213 | -0.0884 | 0.4240 | 0.8230 | -8.1593  | -0.5325 | -0.0931 | 0.4340 | 0.8621 | -9.1008  | -0.4859 | -0.1076 | 0.5520 |
| 0.8946  | -4.8068  | -0.3226 | -0.0554 | 0.2160 | 0.9128 | -4.7174  | -0.2616 | -0.0540 | 0.1770 | 0.9336 | -5.2100  | -0.2290 | -0.0613 | 0.2840 |
| 1.0000  | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 1.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 1.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 |
| 313.15K |          |         |         |        |        |          |         |         |        |        |          |         |         |        |
| 0.0000  | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 0.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 0.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 |
| 0.0949  | -5.7767  | -0.2966 | -0.0598 | 0.1770 | 0.1144 | -6.0802  | -0.3397 | -0.0612 | 0.1850 | 0.1479 | -6.5898  | -0.3076 | -0.0698 | 0.2400 |
| 0.1909  | -9.0076  | -0.5597 | -0.0949 | 0.3630 | 0.2252 | -9.2734  | -0.5952 | -0.0953 | 0.4070 | 0.2809 | -11.1844 | -0.5982 | -0.1219 | 0.6140 |
| 0.2879  | -11.2967 | -0.7271 | -0.1211 | 0.5310 | 0.3326 | -11.2594 | -0.7910 | -0.1180 | 0.5630 | 0.4011 | -13.9161 | -0.8483 | -0.1551 | 0.8340 |
| 0.3861  | -12.6280 | -0.8390 | -0.1374 | 0.7100 | 0.4367 | -13.1673 | -0.9566 | -0.1411 | 0.6480 | 0.5102 | -15.8768 | -0.9949 | -0.1805 | 0.9730 |
| 0.4855  | -13.4475 | -0.9199 | -0.1486 | 0.7860 | 0.5376 | -14.2926 | -1.0434 | -0.1564 | 0.6860 | 0.6098 | -16.1829 | -1.0459 | -0.1864 | 1.0000 |
| 0.5860  | -12.9357 | -0.8409 | -0.1445 | 0.7120 | 0.6356 | -14.2522 | -0.9493 | -0.1586 | 0.6630 | 0.7010 | -16.1554 | -0.9469 | -0.1883 | 0.8650 |
| 0.6876  | -10.9417 | -0.7297 | -0.1228 | 0.5810 | 0.7307 | -12.5272 | -0.8064 | -0.1407 | 0.5410 | 0.7848 | -14.6675 | -0.8100 | -0.1719 | 0.7460 |
| 0.7905  | -8.6832  | -0.5714 | -0.0981 | 0.3660 | 0.8230 | -10.0490 | -0.6361 | -0.1138 | 0.3810 | 0.8621 | -10.9704 | -0.5961 | -0.1280 | 0.4740 |
| 0.8946  | -6.1202  | -0.3626 | -0.0697 | 0.1570 | 0.9128 | -5.6227  | -0.3225 | -0.0636 | 0.1430 | 0.9336 | -6.0565  | -0.3347 | -0.0700 | 0.2180 |
| 1.0000  | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 1.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 1.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 |
| 318.15K |          |         |         |        |        |          |         |         |        |        |          |         |         |        |
| 0.0000  | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 0.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 0.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 |
| 0.0949  | -6.1921  | -0.3423 | -0.0626 | 0.1290 | 0.1144 | -7.3333  | -0.4316 | -0.0720 | 0.1690 | 0.1479 | -7.4716  | -0.3653 | -0.0777 | 0.1790 |
| 0.1909  | -9.8957  | -0.6038 | -0.1020 | 0.2980 | 0.2252 | -10.6427 | -0.7074 | -0.1065 | 0.3580 | 0.2809 | -12.6020 | -0.6777 | -0.1350 | 0.5190 |
| 0.2879  | -12.2489 | -0.7710 | -0.1284 | 0.4620 | 0.3326 | -12.7974 | -0.9021 | -0.1306 | 0.5080 | 0.4011 | -15.6177 | -0.9711 | -0.1711 | 0.7300 |
| 0.3861  | -13.6647 | -0.8821 | -0.1455 | 0.6220 | 0.4367 | -14.6496 | -1.0718 | -0.1529 | 0.5850 | 0.5102 | -17.6717 | -1.1186 | -0.1975 | 0.8610 |
| 0.4855  | -14.5588 | -0.9476 | -0.1574 | 0.7190 | 0.5376 | -15.7172 | -1.1710 | -0.1676 | 0.6250 | 0.6098 | -18.1998 | -1.1471 | -0.2063 | 0.9150 |
| 0.5860  | -13.9105 | -0.8757 | -0.1520 | 0.6550 | 0.6356 | -15.4819 | -1.0861 | -0.1678 | 0.6070 | 0.7010 | -18.0051 | -1.0673 | -0.2063 | 0.7830 |
| 0.6876  | -11.8995 | -0.7705 | -0.1308 | 0.5120 | 0.7307 | -14.0245 | -0.9510 | -0.1539 | 0.4900 | 0.7848 | -16.3085 | -0.9465 | -0.1877 | 0.6580 |
| 0.7905  | -9.5702  | -0.6156 | -0.1059 | 0.3030 | 0.8230 | -11.2197 | -0.7350 | -0.1241 | 0.3490 | 0.8621 | -12.2912 | -0.6905 | -0.1408 | 0.3990 |
| 0.8946  | -6.7261  | -0.3949 | -0.0750 | 0.1150 | 0.9128 | -6.8441  | -0.4104 | -0.0759 | 0.1250 | 0.9336 | -7.0927  | -0.3900 | -0.0805 | 0.1710 |
| 1.0000  | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 1.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 | 1.0000 | 0.0000   | 0.0000  | 0.0000  | 0.0000 |

Figures 3(a), 3(b) and 3(c) show how excess free length varies across DMC compositions in the three systems studied. According to Ramamurthy and Sastry [19], negative  $L_r^E$  values suggest that sound waves must travel a greater distance. This could be due to dominating interactions between different molecules. The presence of ad and  $L_r^E$  minima at the same concentrations supports molecular connections.

Fig 4(a), 4(b) and 4(c) show negative viscosity deviations for all binary systems across the mole fraction range, with negative maximum values around 0.4 mole fractions. Viscosity varies based on the strength of interactions between like and unlike molecules. The sign and magnitude of  $\Delta\eta$  vary with the structural features of liquid components due to differences in molecular size and shape, resulting from geometrical fitting.

Negative variations in viscosity may be caused by dispersion or dipolar forces between molecules due to their size and shape differences.

Physical interactions are often weak or strong, and the sign of  $\Delta\eta$  might be negative or positive. Positive values of  $\Delta\eta$  indicate strong intermolecular interactions, while negative values indicate lesser interactions between dissimilar molecules.

Specific chemical interactions between liquid mixture components, such as hydrogen bond formation and dipole-dipole interactions, cause the structure to become more compact and result in positive viscosity deviations. The sign and magnitude of  $\Delta\eta$  vary with the structural features of liquid components, resulting from geometrical fitting due to differences in molecular size and shape. In this scenario, all three systems have negative  $\Delta\eta$  values, indicating strong interactions such as interstitial accommodation. The results are in good agreement with those derived from data based on  $V^E$  and deviations in compressibility ( $\Delta\beta_{ad}$ )

Table 4 & 5 shows the actual values as well as the theoretical values computed using the Nomoto, Van Dael ideal mixing, impedance, Rao's specific velocity, and Junjie relationships for the analyzed systems at temperatures of 303.15, 308.15, 313.15, and 318.15K along with percentage of deviations. The validity of various theoretical formulae is evaluated by percentage deviation and chi square test for all the mixtures at all the temperatures, which are also shown in Table 4 & 5. It is assumed that all molecules are spherical, although this is not always the case. Nomoto's hypothesis assumes that the volume remains constant when mixed. As a result, no interactions between liquid mixture components were considered. The assumption for the establishment of an ideal mixing relation is that the specific heat ratios of ideal mixtures and volumes are equal. Again, no molecular interactions are taken into consideration.

**Table 3: Experimental and theoretical velocities of DMC + MA, EA and BA systems using various theories**

| DMC+Methyl Acetate |                  |                  |                  |                  |                  |                  |                  |
|--------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| X <sub>1</sub>     | U <sub>EXP</sub> | U <sub>NOM</sub> | U <sub>IMP</sub> | U <sub>VDV</sub> | U <sub>JUN</sub> | U <sub>RAO</sub> | U <sub>KUD</sub> |
| <b>303.15K</b>     |                  |                  |                  |                  |                  |                  |                  |
| 0.0000             | 1106.0           | 1106.0           | 1106.0           | 1106.0           | 1106.0           | 1106.0           | 1106.0           |
| 0.0949             | 1138.7           | 1111.8           | 1113.4           | 1111.9           | 1110.0           | 1128.7           | 1114.1           |
| 0.1909             | 1165.2           | 1117.8           | 1120.8           | 1118.0           | 1114.4           | 1151.0           | 1121.8           |
| 0.2879             | 1187.6           | 1124.1           | 1128.0           | 1124.3           | 1119.4           | 1169.8           | 1129.3           |
| 0.3861             | 1207.0           | 1130.6           | 1135.1           | 1130.9           | 1124.9           | 1185.1           | 1136.6           |
| 0.4855             | 1225.2           | 1137.3           | 1142.0           | 1137.6           | 1131.1           | 1196.4           | 1143.5           |
| 0.5860             | 1230.0           | 1144.3           | 1148.9           | 1144.6           | 1138.0           | 1198.1           | 1150.3           |
| 0.6876             | 1222.6           | 1151.6           | 1155.7           | 1151.9           | 1145.8           | 1197.3           | 1156.9           |
| 0.7905             | 1212.8           | 1159.2           | 1162.3           | 1159.4           | 1154.5           | 1194.4           | 1163.2           |
| 0.8946             | 1201.0           | 1167.1           | 1168.9           | 1167.2           | 1164.3           | 1186.5           | 1169.3           |
| 1.0000             | 1175.3           | 1175.3           | 1175.3           | 1175.3           | 1175.3           | 1175.3           | 1175.3           |
| <b>308.15K</b>     |                  |                  |                  |                  |                  |                  |                  |
| 0.0000             | 1102.9           | 1102.9           | 1102.9           | 1102.9           | 1102.9           | 1102.9           | 1102.9           |
| 0.0949             | 1136.5           | 1107.2           | 1108.4           | 1107.3           | 1105.6           | 1126.2           | 1108.8           |
| 0.1909             | 1160.0           | 1111.6           | 1113.7           | 1111.9           | 1108.7           | 1148.0           | 1114.4           |
| 0.2879             | 1182.0           | 1116.2           | 1119.0           | 1116.6           | 1112.2           | 1164.2           | 1119.9           |
| 0.3861             | 1197.6           | 1120.9           | 1124.2           | 1121.4           | 1116.2           | 1177.2           | 1125.2           |
| 0.4855             | 1214.0           | 1125.9           | 1129.3           | 1126.4           | 1120.7           | 1186.7           | 1130.3           |
| 0.5860             | 1217.0           | 1131.0           | 1134.4           | 1131.5           | 1125.8           | 1186.8           | 1135.3           |
| 0.6876             | 1207.3           | 1136.3           | 1139.3           | 1136.8           | 1131.6           | 1184.6           | 1140.1           |
| 0.7905             | 1198.0           | 1141.9           | 1144.2           | 1142.2           | 1138.1           | 1178.8           | 1144.8           |
| 0.8946             | 1183.0           | 1147.7           | 1149.0           | 1147.9           | 1145.4           | 1169.6           | 1149.3           |
| 1.0000             | 1153.7           | 1153.7           | 1153.7           | 1153.7           | 1153.7           | 1153.7           | 1153.7           |
| <b>313.15K</b>     |                  |                  |                  |                  |                  |                  |                  |
| 0.0000             | 1083.5           | 1083.5           | 1083.5           | 1083.5           | 1083.5           | 1083.5           | 1083.5           |
| 0.0949             | 1120.1           | 1087.8           | 1089.0           | 1088.0           | 1086.3           | 1107.5           | 1089.4           |
| 0.1909             | 1144.5           | 1092.3           | 1094.5           | 1092.6           | 1089.5           | 1129.0           | 1095.2           |
| 0.2879             | 1165.6           | 1097.0           | 1099.8           | 1097.3           | 1093.1           | 1145.2           | 1100.7           |
| 0.3861             | 1181.8           | 1101.8           | 1105.1           | 1102.2           | 1097.2           | 1157.6           | 1106.1           |
| 0.4855             | 1195.5           | 1106.8           | 1110.3           | 1107.3           | 1101.8           | 1167.1           | 1111.3           |
| 0.5860             | 1200.1           | 1112.0           | 1115.4           | 1112.5           | 1106.9           | 1168.3           | 1116.3           |
| 0.6876             | 1192.6           | 1117.4           | 1120.4           | 1117.8           | 1112.8           | 1166.4           | 1121.2           |
| 0.7905             | 1183.5           | 1123.0           | 1125.3           | 1123.4           | 1119.3           | 1160.9           | 1126.0           |
| 0.8946             | 1172.6           | 1128.9           | 1130.2           | 1129.1           | 1126.7           | 1151.8           | 1130.5           |
| 1.0000             | 1135.0           | 1135.0           | 1135.0           | 1135.0           | 1135.0           | 1135.0           | 1135.0           |
| <b>318.15K</b>     |                  |                  |                  |                  |                  |                  |                  |
| 0.0000             | 1062.9           | 1062.9           | 1062.9           | 1062.9           | 1062.9           | 1062.9           | 1062.9           |
| 0.0949             | 1099.2           | 1067.1           | 1068.3           | 1067.3           | 1065.6           | 1088.3           | 1068.7           |
| 0.1909             | 1125.3           | 1071.5           | 1073.6           | 1071.7           | 1068.6           | 1109.3           | 1074.3           |
| 0.2879             | 1145.9           | 1076.0           | 1078.8           | 1076.4           | 1072.1           | 1125.2           | 1079.7           |
| 0.3861             | 1162.0           | 1080.7           | 1083.9           | 1081.1           | 1076.0           | 1137.4           | 1084.9           |
| 0.4855             | 1176.0           | 1085.5           | 1089.0           | 1086.0           | 1080.5           | 1146.1           | 1090.0           |
| 0.5860             | 1179.6           | 1090.6           | 1093.9           | 1091.1           | 1085.5           | 1147.4           | 1094.9           |
| 0.6876             | 1172.8           | 1095.9           | 1098.8           | 1096.3           | 1091.2           | 1145.8           | 1099.6           |
| 0.7905             | 1164.1           | 1101.3           | 1103.6           | 1101.7           | 1097.6           | 1140.4           | 1104.2           |
| 0.8946             | 1152.2           | 1107.1           | 1108.4           | 1107.2           | 1104.8           | 1130.9           | 1108.7           |
| 1.0000             | 1113.0           | 1113.0           | 1113.0           | 1113.0           | 1113.0           | 1113.0           | 1113.0           |

| DMC+Ethyl Acetate |                  |                  |                  |                  |                  |                  |                  |
|-------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| X <sub>1</sub>    | U <sub>EXP</sub> | U <sub>NOM</sub> | U <sub>IMP</sub> | U <sub>VDV</sub> | U <sub>JUN</sub> | U <sub>RAO</sub> | U <sub>KUD</sub> |
| <b>303.15K</b>    |                  |                  |                  |                  |                  |                  |                  |
| 0.0000            | 1117.3           | 1117.3           | 1117.3           | 1117.3           | 1117.3           | 1117.3           | 1117.3           |
| 0.1144            | 1147.0           | 1123.0           | 1125.0           | 1123.4           | 1120.4           | 1130.2           | 1124.2           |
| 0.2252            | 1171.0           | 1128.7           | 1132.2           | 1129.4           | 1124.1           | 1145.0           | 1130.9           |
| 0.3326            | 1193.6           | 1134.5           | 1138.9           | 1135.3           | 1128.3           | 1158.6           | 1137.2           |
| 0.4367            | 1211.3           | 1140.3           | 1145.1           | 1141.2           | 1133.1           | 1170.3           | 1143.3           |
| 0.5376            | 1227.0           | 1146.1           | 1151.0           | 1147.0           | 1138.5           | 1180.0           | 1149.2           |
| 0.6356            | 1234.0           | 1151.9           | 1156.4           | 1152.8           | 1144.5           | 1181.5           | 1154.8           |
| 0.7307            | 1225.5           | 1157.7           | 1161.6           | 1158.5           | 1151.1           | 1182.4           | 1160.2           |
| 0.8230            | 1215.0           | 1163.5           | 1166.4           | 1164.1           | 1158.4           | 1182.3           | 1165.4           |
| 0.9128            | 1195.1           | 1169.4           | 1171.0           | 1169.7           | 1166.5           | 1178.6           | 1170.5           |
| 1.0000            | 1175.3           | 1175.3           | 1175.3           | 1175.3           | 1175.3           | 1175.3           | 1175.3           |
| <b>308.15K</b>    |                  |                  |                  |                  |                  |                  |                  |
| 0.0000            | 1095.2           | 1095.2           | 1095.2           | 1095.2           | 1095.2           | 1095.2           | 1095.2           |
| 0.1144            | 1130.0           | 1101.0           | 1103.0           | 1101.3           | 1098.3           | 1111.2           | 1102.2           |
| 0.2252            | 1156.0           | 1106.7           | 1110.2           | 1107.3           | 1102.0           | 1125.6           | 1108.9           |
| 0.3326            | 1175.7           | 1112.5           | 1117.0           | 1113.3           | 1106.3           | 1139.4           | 1115.3           |
| 0.4367            | 1195.0           | 1118.3           | 1123.3           | 1119.2           | 1111.1           | 1152.1           | 1121.4           |
| 0.5376            | 1214.0           | 1124.2           | 1129.2           | 1125.1           | 1116.5           | 1161.2           | 1127.3           |
| 0.6356            | 1221.2           | 1130.0           | 1134.7           | 1130.9           | 1122.6           | 1163.0           | 1133.0           |
| 0.7307            | 1215.2           | 1135.9           | 1139.9           | 1136.7           | 1129.3           | 1164.6           | 1138.5           |
| 0.8230            | 1204.1           | 1141.8           | 1144.7           | 1142.4           | 1136.7           | 1164.6           | 1143.7           |
| 0.9128            | 1184.0           | 1147.8           | 1149.4           | 1148.1           | 1144.8           | 1159.2           | 1148.8           |
| 1.0000            | 1153.7           | 1153.7           | 1153.7           | 1153.7           | 1153.7           | 1153.7           | 1153.7           |
| <b>313.15K</b>    |                  |                  |                  |                  |                  |                  |                  |
| 0.0000            | 1080.7           | 1080.7           | 1080.7           | 1080.7           | 1080.7           | 1080.7           | 1080.7           |
| 0.1144            | 1120.0           | 1086.0           | 1087.9           | 1086.4           | 1083.5           | 1098.4           | 1087.2           |
| 0.2252            | 1146.0           | 1091.4           | 1094.7           | 1092.0           | 1086.9           | 1113.6           | 1093.4           |
| 0.3326            | 1166.3           | 1096.8           | 1100.9           | 1097.6           | 1090.8           | 1126.9           | 1099.3           |
| 0.4367            | 1188.0           | 1102.2           | 1106.8           | 1103.1           | 1095.2           | 1139.3           | 1105.0           |
| 0.5376            | 1205.5           | 1107.6           | 1112.2           | 1108.5           | 1100.2           | 1148.8           | 1110.5           |
| 0.6356            | 1215.0           | 1113.0           | 1117.4           | 1113.9           | 1105.9           | 1151.2           | 1115.8           |
| 0.7307            | 1210.0           | 1118.5           | 1122.2           | 1119.3           | 1112.1           | 1151.5           | 1120.9           |
| 0.8230            | 1198.2           | 1124.0           | 1126.7           | 1124.6           | 1119.0           | 1150.3           | 1125.8           |
| 0.9128            | 1170.7           | 1129.5           | 1131.0           | 1129.8           | 1126.7           | 1143.1           | 1130.5           |
| 1.0000            | 1135.0           | 1135.0           | 1135.0           | 1135.0           | 1135.0           | 1135.0           | 1135.0           |
| <b>318.15K</b>    |                  |                  |                  |                  |                  |                  |                  |
| 0.0000            | 1052.4           | 1052.4           | 1052.4           | 1052.4           | 1052.4           | 1052.4           | 1052.4           |
| 0.1144            | 1096.0           | 1058.3           | 1060.5           | 1058.7           | 1055.7           | 1073.3           | 1059.6           |
| 0.2252            | 1122.0           | 1064.3           | 1068.0           | 1064.9           | 1059.6           | 1089.6           | 1066.6           |
| 0.3326            | 1143.4           | 1070.3           | 1075.0           | 1071.1           | 1064.0           | 1103.4           | 1073.2           |
| 0.4367            | 1164.7           | 1076.3           | 1081.5           | 1077.2           | 1069.0           | 1116.4           | 1079.6           |
| 0.5376            | 1182.1           | 1082.4           | 1087.6           | 1083.3           | 1074.6           | 1127.0           | 1085.7           |
| 0.6356            | 1191.0           | 1088.4           | 1093.3           | 1089.3           | 1080.8           | 1130.6           | 1091.6           |
| 0.7307            | 1190.0           | 1094.5           | 1098.7           | 1095.3           | 1087.8           | 1132.1           | 1097.3           |
| 0.8230            | 1178.0           | 1100.7           | 1103.7           | 1101.3           | 1095.4           | 1130.0           | 1102.7           |
| 0.9128            | 1153.9           | 1106.8           | 1108.5           | 1107.2           | 1103.8           | 1123.4           | 1107.9           |
| 1.0000            | 1113.0           | 1113.0           | 1113.0           | 1113.0           | 1113.0           | 1113.0           | 1113.0           |

| DMC+Butyl Acetate |        |        |        |        |        |        |        |
|-------------------|--------|--------|--------|--------|--------|--------|--------|
| X <sub>1</sub>    | UEXP   | UNOM   | UIMP   | UVDV   | UJUN   | URAO   | UKUD   |
| <b>303.15K</b>    |        |        |        |        |        |        |        |
| 0.0000            | 1165.2 | 1165.2 | 1165.2 | 1165.2 | 1165.2 | 1165.2 | 1165.2 |
| 0.1479            | 1203.0 | 1166.5 | 1167.0 | 1166.6 | 1163.9 | 1152.3 | 1166.4 |
| 0.2809            | 1230.0 | 1167.7 | 1168.4 | 1167.9 | 1163.3 | 1147.5 | 1167.6 |
| 0.4011            | 1251.7 | 1168.8 | 1169.7 | 1169.1 | 1163.4 | 1147.2 | 1168.7 |
| 0.5102            | 1268.4 | 1169.9 | 1170.8 | 1170.2 | 1164.1 | 1150.0 | 1169.7 |
| 0.6098            | 1276.0 | 1170.9 | 1171.8 | 1171.2 | 1165.2 | 1155.2 | 1170.7 |
| 0.7010            | 1277.9 | 1171.9 | 1172.7 | 1172.1 | 1166.6 | 1156.7 | 1171.7 |
| 0.7848            | 1262.8 | 1172.8 | 1173.4 | 1173.0 | 1168.4 | 1159.4 | 1172.7 |
| 0.8621            | 1242.6 | 1173.7 | 1174.1 | 1173.8 | 1170.5 | 1164.3 | 1173.6 |
| 0.9336            | 1210.4 | 1174.5 | 1174.7 | 1174.6 | 1172.8 | 1168.2 | 1174.5 |
| 1.0000            | 1175.3 | 1175.3 | 1175.3 | 1175.3 | 1175.3 | 1175.3 | 1175.3 |
| <b>308.15K</b>    |        |        |        |        |        |        |        |
| 0.0000            | 1149.4 | 1149.4 | 1149.4 | 1149.4 | 1149.4 | 1149.4 | 1149.4 |
| 0.1479            | 1192.0 | 1149.9 | 1150.1 | 1150.0 | 1147.5 | 1138.1 | 1149.9 |
| 0.2809            | 1225.5 | 1150.5 | 1150.8 | 1150.5 | 1146.3 | 1134.0 | 1150.4 |
| 0.4011            | 1246.0 | 1151.0 | 1151.3 | 1151.0 | 1145.8 | 1133.8 | 1150.9 |
| 0.5102            | 1265.7 | 1151.4 | 1151.8 | 1151.5 | 1145.9 | 1136.5 | 1151.3 |
| 0.6098            | 1270.5 | 1151.8 | 1152.2 | 1151.9 | 1146.4 | 1140.4 | 1151.8 |
| 0.7010            | 1274.6 | 1152.3 | 1152.6 | 1152.3 | 1147.3 | 1142.1 | 1152.2 |
| 0.7848            | 1261.7 | 1152.6 | 1152.9 | 1152.7 | 1148.5 | 1143.9 | 1152.6 |
| 0.8621            | 1232.5 | 1153.0 | 1153.2 | 1153.1 | 1150.0 | 1147.7 | 1153.0 |
| 0.9336            | 1197.8 | 1153.4 | 1153.5 | 1153.4 | 1151.8 | 1149.5 | 1153.3 |
| 1.0000            | 1153.7 | 1153.7 | 1153.7 | 1153.7 | 1153.7 | 1153.7 | 1153.7 |
| <b>313.15K</b>    |        |        |        |        |        |        |        |
| 0.0000            | 1130.1 | 1130.1 | 1130.1 | 1130.1 | 1130.1 | 1130.1 | 1130.1 |
| 0.1479            | 1177.0 | 1130.7 | 1131.0 | 1130.8 | 1128.3 | 1121.2 | 1130.7 |
| 0.2809            | 1215.0 | 1131.3 | 1131.7 | 1131.4 | 1127.3 | 1118.2 | 1131.2 |
| 0.4011            | 1241.0 | 1131.9 | 1132.3 | 1132.0 | 1126.9 | 1119.5 | 1131.8 |
| 0.5102            | 1262.0 | 1132.4 | 1132.8 | 1132.5 | 1127.0 | 1122.4 | 1132.3 |
| 0.6098            | 1268.0 | 1132.9 | 1133.3 | 1133.0 | 1127.6 | 1126.1 | 1132.8 |
| 0.7010            | 1271.0 | 1133.4 | 1133.7 | 1133.4 | 1128.5 | 1128.0 | 1133.3 |
| 0.7848            | 1258.9 | 1133.8 | 1134.1 | 1133.9 | 1129.8 | 1131.0 | 1133.7 |
| 0.8621            | 1225.4 | 1134.2 | 1134.4 | 1134.3 | 1131.3 | 1133.1 | 1134.2 |
| 0.9336            | 1183.0 | 1134.6 | 1134.7 | 1134.6 | 1133.1 | 1134.9 | 1134.6 |
| 1.0000            | 1135.0 | 1135.0 | 1135.0 | 1135.0 | 1135.0 | 1135.0 | 1135.0 |
| <b>318.15K</b>    |        |        |        |        |        |        |        |
| 0.0000            | 1110.4 | 1110.4 | 1110.4 | 1110.4 | 1110.4 | 1110.4 | 1110.4 |
| 0.1479            | 1160.0 | 1110.7 | 1110.9 | 1110.7 | 1108.4 | 1102.8 | 1110.7 |
| 0.2809            | 1200.0 | 1111.0 | 1111.2 | 1111.1 | 1107.1 | 1100.1 | 1111.0 |
| 0.4011            | 1227.0 | 1111.3 | 1111.6 | 1111.4 | 1106.5 | 1102.4 | 1111.3 |
| 0.5102            | 1248.0 | 1111.6 | 1111.9 | 1111.6 | 1106.4 | 1105.2 | 1111.6 |
| 0.6098            | 1256.0 | 1111.9 | 1112.1 | 1111.9 | 1106.7 | 1108.1 | 1111.8 |
| 0.7010            | 1257.2 | 1112.1 | 1112.3 | 1112.2 | 1107.5 | 1110.5 | 1112.1 |
| 0.7848            | 1243.4 | 1112.4 | 1112.5 | 1112.4 | 1108.5 | 1114.0 | 1112.3 |
| 0.8621            | 1208.7 | 1112.6 | 1112.7 | 1112.6 | 1109.8 | 1114.6 | 1112.6 |
| 0.9336            | 1166.0 | 1112.8 | 1112.9 | 1112.8 | 1111.3 | 1115.0 | 1112.8 |
| 1.0000            | 1113.0 | 1113.0 | 1113.0 | 1113.0 | 1113.0 | 1113.0 | 1113.0 |



**Table 4 Percentage Deviations and Interaction Parameters ( $\alpha$ )**

| DMC+Methyl Acetate |                 |                   |                   |                   |                   |                   |                                              |          |
|--------------------|-----------------|-------------------|-------------------|-------------------|-------------------|-------------------|----------------------------------------------|----------|
| X <sub>1</sub>     | %U <sub>N</sub> | %U <sub>imp</sub> | %U <sub>VDV</sub> | %U <sub>JUN</sub> | %U <sub>RAO</sub> | %U <sub>KUD</sub> | U <sup>2</sup> /U <sup>2</sup> <sub>mx</sub> | $\alpha$ |
| <b>303.15K</b>     |                 |                   |                   |                   |                   |                   |                                              |          |
| 0.0000             | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000   |
| 0.0949             | -2.3572         | -2.2138           | -2.3484           | -2.5189           | -0.8779           | -2.1603           | 1.0487                                       | 0.0487   |
| 0.1909             | -4.0652         | -3.8135           | -4.0492           | -4.3592           | -1.2197           | -3.7231           | 1.0862                                       | 0.0862   |
| 0.2879             | -5.3480         | -5.0205           | -5.3267           | -5.7449           | -1.5014           | -4.9072           | 1.1157                                       | 0.1157   |
| 0.3861             | -6.3329         | -5.9607           | -6.3082           | -6.8015           | -1.8110           | -5.8366           | 1.1392                                       | 0.1392   |
| 0.4855             | -7.1755         | -6.7893           | -7.1493           | -7.6813           | -2.3524           | -6.6652           | 1.1599                                       | 0.1599   |
| 0.5860             | -6.9676         | -6.5940           | -6.9417           | -7.4773           | -2.5897           | -6.4784           | 1.1548                                       | 0.1548   |
| 0.6876             | -5.8105         | -5.4777           | -5.7868           | -6.2842           | -2.0720           | -5.3784           | 1.1266                                       | 0.1266   |
| 0.7905             | -4.4206         | -4.1618           | -4.4018           | -4.8055           | -1.5191           | -4.0874           | 1.0942                                       | 0.0942   |
| 0.8946             | -2.8258         | -2.6768           | -2.8147           | -3.0576           | -1.2103           | -2.6356           | 1.0588                                       | 0.0588   |
| 1.0000             | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000   |
| <b>308.15K</b>     |                 |                   |                   |                   |                   |                   |                                              |          |
| 0.0000             | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000   |
| 0.0949             | -2.5809         | -2.4752           | -2.5675           | -2.7171           | -0.9045           | -2.4408           | 1.0534                                       | 0.0534   |
| 0.1909             | -4.1732         | -3.9874           | -4.1491           | -4.4209           | -1.0332           | -3.9290           | 1.0884                                       | 0.0884   |
| 0.2879             | -5.5688         | -5.3271           | -5.5367           | -5.9023           | -1.5072           | -5.2539           | 1.1207                                       | 0.1207   |
| 0.3861             | -6.4016         | -6.1262           | -6.3641           | -6.7954           | -1.7029           | -6.0456           | 1.1406                                       | 0.1406   |
| 0.4855             | -7.2592         | -6.9731           | -7.2193           | -7.6833           | -2.2514           | -6.8924           | 1.1617                                       | 0.1617   |
| 0.5860             | -7.0661         | -6.7891           | -7.0266           | -7.4925           | -2.4815           | -6.7137           | 1.1569                                       | 0.1569   |
| 0.6876             | -5.8775         | -5.6304           | -5.8413           | -6.2730           | -1.8788           | -5.5654           | 1.1279                                       | 0.1279   |
| 0.7905             | -4.6834         | -4.4914           | -4.6546           | -5.0033           | -1.6067           | -4.4427           | 1.1000                                       | 0.1000   |
| 0.8946             | -2.9861         | -2.8753           | -2.9691           | -3.1785           | -1.1365           | -2.8483           | 1.0621                                       | 0.0621   |
| 1.0000             | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000   |
| <b>313.15K</b>     |                 |                   |                   |                   |                   |                   |                                              |          |
| 0.0000             | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000   |
| 0.0949             | -2.8767         | -2.7698           | -2.8644           | -3.0119           | -1.1201           | -2.7330           | 1.0598                                       | 0.0598   |
| 0.1909             | -4.5599         | -4.3721           | -4.5376           | -4.8054           | -1.3550           | -4.3097           | 1.0973                                       | 0.0973   |
| 0.2879             | -5.8866         | -5.6421           | -5.8569           | -6.2172           | -1.7485           | -5.5638           | 1.1283                                       | 0.1283   |
| 0.3861             | -6.7651         | -6.4867           | -6.7305           | -7.1552           | -2.0423           | -6.4006           | 1.1495                                       | 0.1495   |
| 0.4855             | -7.4174         | -7.1276           | -7.3805           | -7.8383           | -2.3718           | -7.0411           | 1.1657                                       | 0.1657   |
| 0.5860             | -7.3399         | -7.0598           | -7.3034           | -7.7625           | -2.6532           | -6.9791           | 1.1638                                       | 0.1638   |
| 0.6876             | -6.3039         | -6.0544           | -6.2706           | -6.6952           | -2.1980           | -5.9850           | 1.1383                                       | 0.1383   |
| 0.7905             | -5.1100         | -4.9161           | -5.0835           | -5.4264           | -1.9098           | -4.8641           | 1.1100                                       | 0.1100   |
| 0.8946             | -3.7275         | -3.6161           | -3.7119           | -3.9171           | -1.7760           | -3.5872           | 1.0786                                       | 0.0786   |
| 1.0000             | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000   |
| <b>318.15K</b>     |                 |                   |                   |                   |                   |                   |                                              |          |
| 0.0000             | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000   |
| 0.0949             | -2.9213         | -2.8130           | -2.9079           | -3.0596           | -0.9961           | -2.7779           | 1.0608                                       | 0.0608   |
| 0.1909             | -4.7872         | -4.5972           | -4.7629           | -5.0379           | -1.4231           | -4.5379           | 1.1025                                       | 0.1025   |
| 0.2879             | -6.0978         | -5.8505           | -6.0655           | -6.4357           | -1.7993           | -5.7760           | 1.1333                                       | 0.1333   |
| 0.3861             | -6.9987         | -6.7172           | -6.9611           | -7.3974           | -2.1188           | -6.6354           | 1.1552                                       | 0.1552   |
| 0.4855             | -7.6917         | -7.3989           | -7.6516           | -8.1220           | -2.5460           | -7.3168           | 1.1726                                       | 0.1726   |
| 0.5860             | -7.5468         | -7.2634           | -7.5071           | -7.9794           | -2.7292           | -7.1868           | 1.1689                                       | 0.1689   |
| 0.6876             | -6.5621         | -6.3098           | -6.5259           | -6.9626           | -2.3067           | -6.2440           | 1.1445                                       | 0.1445   |
| 0.7905             | -5.3943         | -5.1983           | -5.3655           | -5.7184           | -2.0356           | -5.1490           | 1.1166                                       | 0.1166   |
| 0.8946             | -3.9174         | -3.8046           | -3.9004           | -4.1119           | -1.8505           | -3.7773           | 1.0828                                       | 0.0828   |
| 1.0000             | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000   |

| DMC+Ethyl Acetate |                 |                   |                   |                   |                   |                   |                                              |        |
|-------------------|-----------------|-------------------|-------------------|-------------------|-------------------|-------------------|----------------------------------------------|--------|
| X <sub>1</sub>    | %U <sub>N</sub> | %U <sub>imp</sub> | %U <sub>VDV</sub> | %U <sub>JUN</sub> | %U <sub>RAO</sub> | %U <sub>KUD</sub> | U <sup>2</sup> /U <sup>2</sup> <sub>mx</sub> | α      |
| 303.15K           |                 |                   |                   |                   |                   |                   |                                              |        |
| 0.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000 |
| 0.1144            | -2.0914         | -1.9162           | -2.0615           | -2.3177           | -1.4634           | -1.9859           | 1.0425                                       | 0.0425 |
| 0.2252            | -3.6086         | -3.3138           | -3.5567           | -4.0075           | -2.2230           | -3.4286           | 1.0751                                       | 0.0751 |
| 0.3326            | -4.9518         | -4.5847           | -4.8853           | -5.4722           | -2.9341           | -4.7247           | 1.1054                                       | 0.1054 |
| 0.4367            | -5.8643         | -5.4640           | -5.7896           | -6.4582           | -3.3811           | -5.6133           | 1.1267                                       | 0.1267 |
| 0.5376            | -6.5970         | -6.1978           | -6.5204           | -7.2164           | -3.8281           | -6.3436           | 1.1444                                       | 0.1444 |
| 0.6356            | -6.6560         | -6.2862           | -6.5831           | -7.2562           | -4.2518           | -6.4185           | 1.1459                                       | 0.1459 |
| 0.7307            | -5.5329         | -5.2164           | -5.4689           | -6.0702           | -3.5131           | -5.3274           | 1.1191                                       | 0.1191 |
| 0.8230            | -4.2351         | -3.9987           | -4.1861           | -4.6549           | -2.6877           | -4.0799           | 1.0893                                       | 0.0893 |
| 0.9128            | -2.1495         | -2.0179           | -2.1215           | -2.3938           | -1.3786           | -2.0622           | 1.0438                                       | 0.0438 |
| 1.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000 |
| 308.15K           |                 |                   |                   |                   |                   |                   |                                              |        |
| 0.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000 |
| 0.1144            | -2.5706         | -2.3896           | -2.5402           | -2.8015           | -1.6674           | -2.4615           | 1.0528                                       | 0.0528 |
| 0.2252            | -4.2625         | -3.9586           | -4.2097           | -4.6688           | -2.6319           | -4.0766           | 1.0898                                       | 0.0898 |
| 0.3326            | -5.3737         | -4.9944           | -5.3058           | -5.9051           | -3.0878           | -5.1384           | 1.1152                                       | 0.1152 |
| 0.4367            | -6.4152         | -6.0022           | -6.3391           | -7.0211           | -3.5900           | -6.1556           | 1.1399                                       | 0.1399 |
| 0.5376            | -7.3989         | -6.9883           | -7.3211           | -8.0295           | -4.3482           | -7.1376           | 1.1642                                       | 0.1642 |
| 0.6356            | -7.4650         | -7.0847           | -7.3909           | -8.0762           | -4.7676           | -7.2201           | 1.1660                                       | 0.1660 |
| 0.7307            | -6.5240         | -6.1991           | -6.4591           | -7.0704           | -4.1617           | -6.3125           | 1.1429                                       | 0.1429 |
| 0.8230            | -5.1719         | -4.9290           | -5.1222           | -5.5994           | -3.2811           | -5.0121           | 1.1109                                       | 0.1109 |
| 0.9128            | -3.0615         | -2.9263           | -3.0332           | -3.3106           | -2.0955           | -2.9716           | 1.0635                                       | 0.0635 |
| 1.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000 |
| 313.15K           |                 |                   |                   |                   |                   |                   |                                              |        |
| 0.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000 |
| 0.1144            | -3.0322         | -2.8622           | -3.0018           | -3.2566           | -1.9276           | -2.9308           | 1.0629                                       | 0.0629 |
| 0.2252            | -4.7645         | -4.4792           | -4.7119           | -5.1590           | -2.8254           | -4.5918           | 1.1013                                       | 0.1013 |
| 0.3326            | -5.9608         | -5.6051           | -5.8932           | -6.4762           | -3.3740           | -5.7424           | 1.1292                                       | 0.1292 |
| 0.4367            | -7.2240         | -6.8375           | -7.1484           | -7.8101           | -4.0993           | -6.9835           | 1.1599                                       | 0.1599 |
| 0.5376            | -8.1213         | -7.7366           | -8.0439           | -8.7315           | -4.7060           | -7.8788           | 1.1826                                       | 0.1826 |
| 0.6356            | -8.3952         | -8.0397           | -8.3218           | -8.9852           | -5.2503           | -8.1684           | 1.1898                                       | 0.1898 |
| 0.7307            | -7.5622         | -7.2587           | -7.4978           | -8.0888           | -4.8345           | -7.3663           | 1.1687                                       | 0.1687 |
| 0.8230            | -6.1927         | -5.9657           | -6.1434           | -6.6047           | -3.9954           | -6.0446           | 1.1352                                       | 0.1352 |
| 0.9128            | -3.5196         | -3.3924           | -3.4913           | -3.7610           | -2.3594           | -3.4357           | 1.0737                                       | 0.0737 |
| 1.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000 |
| 318.15K           |                 |                   |                   |                   |                   |                   |                                              |        |
| 0.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000 |
| 0.1144            | -3.4358         | -3.2402           | -3.4048           | -3.6765           | -2.0722           | -3.3167           | 1.0717                                       | 0.0717 |
| 0.2252            | -5.1415         | -4.8132           | -5.0877           | -5.5653           | -2.8891           | -4.9387           | 1.1101                                       | 0.1101 |
| 0.3326            | -6.3926         | -5.9836           | -6.3235           | -6.9464           | -3.5005           | -6.1364           | 1.1396                                       | 0.1396 |
| 0.4367            | -7.5876         | -7.1431           | -7.5102           | -8.2185           | -4.1455           | -7.3056           | 1.1690                                       | 0.1690 |
| 0.5376            | -8.4341         | -7.9917           | -8.3548           | -9.0922           | -4.6606           | -8.1499           | 1.1906                                       | 0.1906 |
| 0.6356            | -8.6068         | -8.1977           | -8.5315           | -9.2448           | -5.0648           | -8.3410           | 1.1952                                       | 0.1952 |
| 0.7307            | -8.0214         | -7.6732           | -7.9556           | -8.5901           | -4.8681           | -7.7926           | 1.1803                                       | 0.1803 |
| 0.8230            | -6.5644         | -6.3039           | -6.5139           | -7.0105           | -4.0707           | -6.3914           | 1.1442                                       | 0.1442 |
| 0.9128            | -4.0828         | -3.9371           | -4.0538           | -4.3440           | -2.6451           | -3.9851           | 1.0863                                       | 0.0863 |
| 1.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 1.0000                                       | 0.0000 |

| DMC+Butyl Acetate |                 |                   |                   |                   |                   |                 |                                              |        |
|-------------------|-----------------|-------------------|-------------------|-------------------|-------------------|-----------------|----------------------------------------------|--------|
| X <sub>1</sub>    | %U <sub>N</sub> | %U <sub>imp</sub> | %U <sub>VDV</sub> | %U <sub>JUN</sub> | %U <sub>RAO</sub> | %U <sub>K</sub> | U <sup>2</sup> /U <sup>2</sup> <sub>mx</sub> | α      |
| 303.15K           |                 |                   |                   |                   |                   |                 |                                              |        |
| 0.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000          | 1.0000                                       | 0.0000 |
| 0.1479            | -3.0351         | -2.9962           | -3.0246           | -3.2520           | -4.2141           | -3.0421         | 1.0634                                       | 0.0634 |
| 0.2809            | -5.0652         | -5.0045           | -5.0481           | -5.4203           | -6.7068           | -5.0767         | 1.1092                                       | 0.1092 |
| 0.4011            | -6.6198         | -6.5491           | -6.5992           | -7.0523           | -8.3486           | -6.6340         | 1.1463                                       | 0.1463 |
| 0.5102            | -7.7613         | -7.6889           | -7.7396           | -8.2229           | -9.3286           | -7.7766         | 1.1748                                       | 0.1748 |
| 0.6098            | -8.2338         | -8.1654           | -8.2127           | -8.6871           | -9.4662           | -8.2489         | 1.1870                                       | 0.1870 |
| 0.7010            | -8.2943         | -8.2341           | -8.2752           | -8.7072           | -9.4808           | -8.3080         | 1.1886                                       | 0.1886 |
| 0.7848            | -7.1268         | -7.0778           | -7.1110           | -7.4748           | -8.1886           | -7.1385         | 1.1590                                       | 0.1590 |
| 0.8621            | -5.5492         | -5.5141           | -5.5376           | -5.8061           | -6.3015           | -5.5578         | 1.1207                                       | 0.1207 |
| 0.9336            | -2.9626         | -2.9438           | -2.9563           | -3.1043           | -3.4817           | -2.9674         | 1.0619                                       | 0.0619 |
| 1.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000          | 1.0000                                       | 0.0000 |
| 308.15K           |                 |                   |                   |                   |                   |                 |                                              |        |
| 0.0000            | 0.0000          | 0.0000            | 0.0000            | 0.0000            | 0.0000            | 0.0000          | 1.0000                                       | 0.0000 |

|                |          |          |          |          |          |          |        |        |
|----------------|----------|----------|----------|----------|----------|----------|--------|--------|
| 0.1479         | -3.5278  | -3.5111  | -3.5247  | -3.7348  | -4.5245  | -3.5309  | 1.0744 | 0.0744 |
| 0.2809         | -6.1229  | -6.0969  | -6.1177  | -6.4594  | -7.4693  | -6.1280  | 1.1346 | 0.1346 |
| 0.4011         | -7.6284  | -7.5982  | -7.6221  | -8.0380  | -9.0019  | -7.6347  | 1.1718 | 0.1718 |
| 0.5102         | -9.0298  | -8.9990  | -9.0232  | -9.4654  | -10.2084 | -9.0366  | 1.2082 | 0.2082 |
| 0.6098         | -9.3394  | -9.3101  | -9.3328  | -9.7674  | -10.2401 | -9.3461  | 1.2165 | 0.2165 |
| 0.7010         | -9.5988  | -9.5731  | -9.5928  | -9.9875  | -10.3937 | -9.6049  | 1.2235 | 0.2235 |
| 0.7848         | -8.6436  | -8.6227  | -8.6386  | -8.9703  | -9.3333  | -8.6488  | 1.1980 | 0.1980 |
| 0.8621         | -6.4492  | -6.4342  | -6.4455  | -6.6919  | -6.8815  | -6.4531  | 1.1425 | 0.1425 |
| 0.9336         | -3.7097  | -3.7016  | -3.7077  | -3.8437  | -4.0291  | -3.7119  | 1.0785 | 0.0785 |
| 1.0000         | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 1.0000 | 0.0000 |
| <b>313.15K</b> |          |          |          |          |          |          |        |        |
| 0.0000         | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 1.0000 | 0.0000 |
| 0.1479         | -3.9315  | -3.9124  | -3.9276  | -4.1359  | -4.7371  | -3.9352  | 1.0834 | 0.0834 |
| 0.2809         | -6.8877  | -6.8582  | -6.8813  | -7.2186  | -7.9646  | -6.8937  | 1.1533 | 0.1533 |
| 0.4011         | -8.7938  | -8.7595  | -8.7860  | -9.1947  | -9.7890  | -8.8012  | 1.2019 | 0.2019 |
| 0.5102         | -10.2701 | -10.2351 | -10.2618 | -10.6958 | -11.0634 | -10.2780 | 1.2418 | 0.2418 |
| 0.6098         | -10.6557 | -10.6226 | -10.6476 | -11.0736 | -11.1908 | -10.6635 | 1.2525 | 0.2525 |
| 0.7010         | -10.8298 | -10.8007 | -10.8224 | -11.2096 | -11.2524 | -10.8369 | 1.2574 | 0.2574 |
| 0.7848         | -9.9339  | -9.9103  | -9.9278  | -10.2529 | -10.1600 | -9.9399  | 1.2326 | 0.2326 |
| 0.8621         | -7.4435  | -7.4264  | -7.4390  | -7.6812  | -7.5355  | -7.4480  | 1.1672 | 0.1672 |
| 0.9336         | -4.0897  | -4.0805  | -4.0872  | -4.2218  | -4.0639  | -4.0922  | 1.0870 | 0.0870 |
| 1.0000         | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 1.0000 | 0.0000 |
| <b>318.15K</b> |          |          |          |          |          |          |        |        |
| 0.0000         | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 1.0000 | 0.0000 |
| 0.1479         | -4.2472  | -4.2369  | -4.2464  | -4.4484  | -4.9317  | -4.2492  | 1.0907 | 0.0907 |
| 0.2809         | -7.4130  | -7.3971  | -7.4115  | -7.7379  | -8.3214  | -7.4162  | 1.1665 | 0.1665 |
| 0.4011         | -9.4264  | -9.4079  | -9.4245  | -9.8193  | -10.1517 | -9.4304  | 1.2189 | 0.2189 |
| 0.5102         | -10.9282 | -10.9094 | -10.9261 | -11.3453 | -11.4444 | -10.9325 | 1.2604 | 0.2604 |
| 0.6098         | -11.4747 | -11.4569 | -11.4725 | -11.8833 | -11.7791 | -11.4789 | 1.2760 | 0.2760 |
| 0.7010         | -11.5394 | -11.5238 | -11.5374 | -11.9111 | -11.6692 | -11.5433 | 1.2779 | 0.2779 |
| 0.7848         | -10.5387 | -10.5260 | -10.5370 | -10.8511 | -10.4081 | -10.5420 | 1.2494 | 0.2494 |
| 0.8621         | -7.9519  | -7.9427  | -7.9506  | -8.1850  | -7.7819  | -7.9543  | 1.1802 | 0.1802 |
| 0.9336         | -4.5628  | -4.5578  | -4.5621  | -4.6924  | -4.3717  | -4.5642  | 1.0979 | 0.0979 |
| 1.0000         | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 0.0000   | 1.0000 | 0.0000 |

**Table 5: Value of chi-square and the standard deviation  $\sigma$  for the binary mixtures of DMC with MA, EA and BA at different temperatures.**

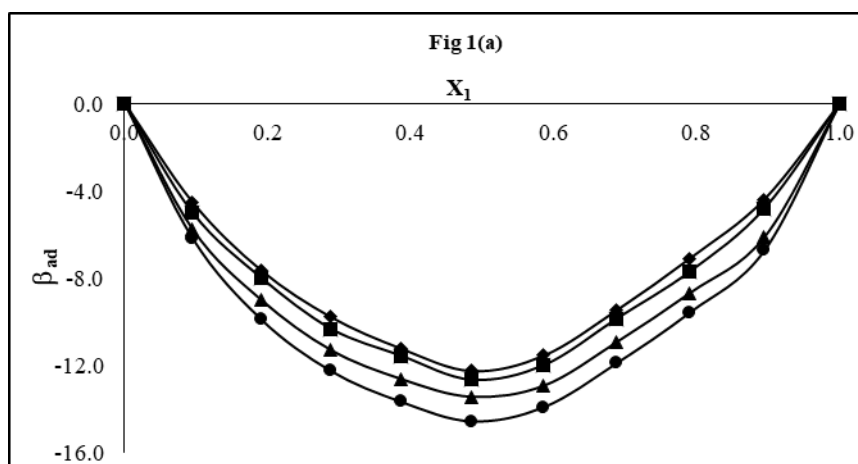
|                             | UNOM    | Uimp    | UVDV    | UJUN    | URAO    | UKUD    |
|-----------------------------|---------|---------|---------|---------|---------|---------|
| <b>DMC + Methyl Acetate</b> |         |         |         |         |         |         |
| <b>303.15K</b>              |         |         |         |         |         |         |
| $\sigma$                    | -0.4798 | -0.4508 | -0.4779 | -0.5184 | -0.1544 | 3.8066  |
| $\chi^2$                    | 30.5319 | 27.1595 | 30.2960 | 35.2974 | 3.4083  | 1.5939  |
| <b>308.15K</b>              |         |         |         |         |         |         |
| $\sigma$                    | -0.4941 | -0.4725 | -0.4911 | -0.5265 | -0.1476 | 4.0120  |
| $\chi^2$                    | 31.6775 | 29.1238 | 31.3137 | 35.6975 | 3.0856  | 1.7706  |
| <b>313.15K</b>              |         |         |         |         |         |         |
| $\sigma$                    | -0.5317 | -0.5097 | -0.5289 | -0.5640 | -0.1753 | 4.3149  |
| $\chi^2$                    | 35.2559 | 32.5501 | 34.9043 | 39.4212 | 4.0950  | 2.0480  |
| <b>318.15K</b>              |         |         |         |         |         |         |
| $\sigma$                    | 0.0485  | -0.0107 | -0.2491 | -0.0569 | 0.0280  | 4.4910  |
| $\chi^2$                    | 0.3653  | 0.01784 | 9.14227 | 0.49645 | 0.12337 | 2.21861 |
| <b>DMC + Ethyl Acetate</b>  |         |         |         |         |         |         |
| <b>303.15K</b>              |         |         |         |         |         |         |
| $\sigma$                    | -0.4399 | -0.4101 | -0.4342 | -0.4864 | -0.2650 | -3.6349 |
| $\chi^2$                    | 26.4088 | 23.1860 | 25.7746 | 31.8435 | 9.8829  | 1.4534  |
| <b>308.15K</b>              |         |         |         |         |         |         |
| $\sigma$                    | -0.5127 | -0.4816 | -0.5068 | -0.5609 | -0.3074 | -4.2260 |
| $\chi^2$                    | 34.1142 | 30.3620 | 33.3857 | 40.3372 | 12.7680 | 1.9645  |
| <b>313.15K</b>              |         |         |         |         |         |         |
| $\sigma$                    | -0.5869 | -0.5572 | -0.5809 | -0.6342 | -0.3478 | -4.8311 |
| $\chi^2$                    | 43.4543 | 39.4909 | 42.6406 | 50.1755 | 16.0666 | 2.5674  |

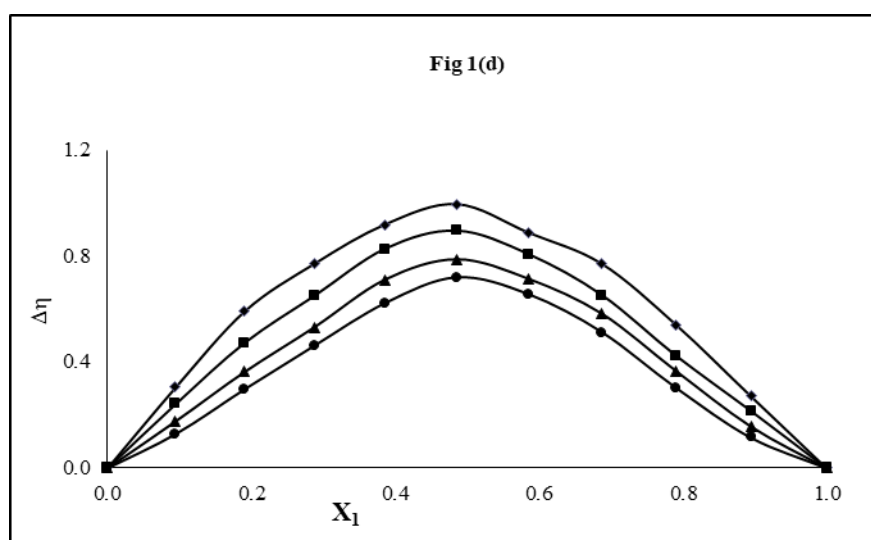
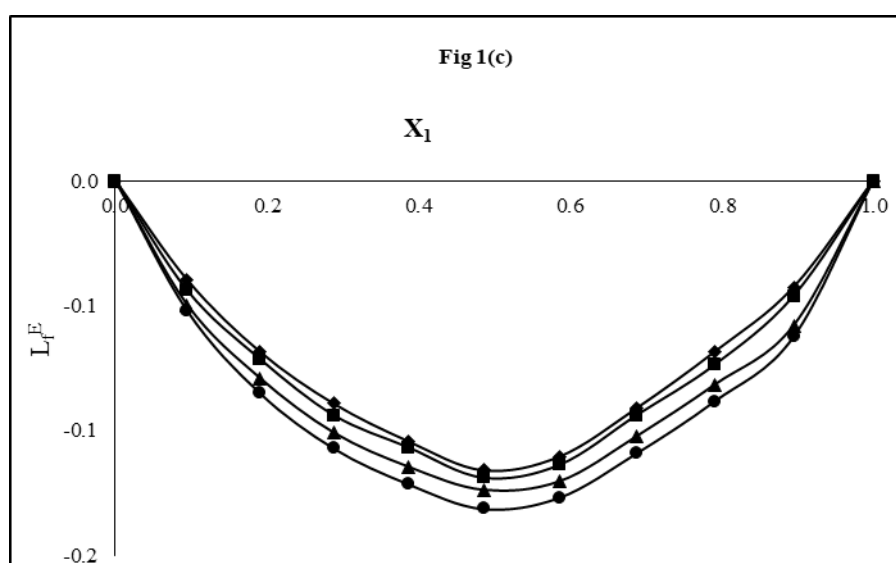
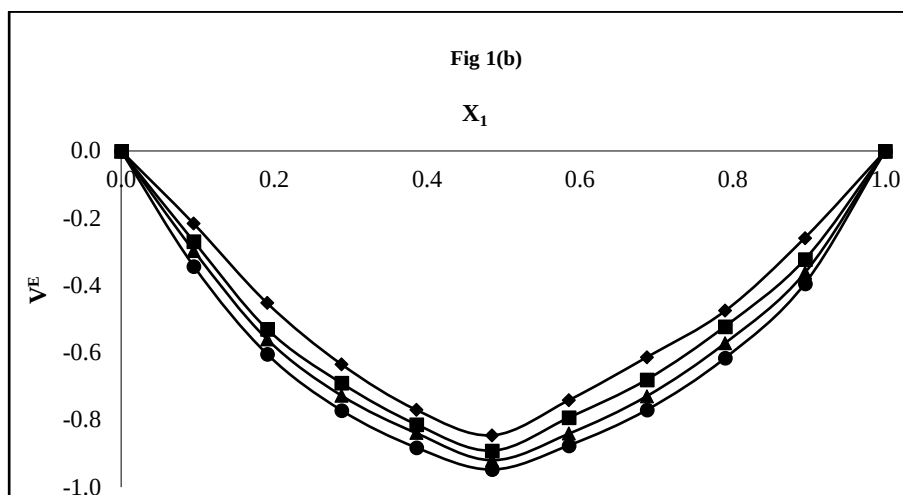
| 318.15K             |         |         |         |         |         |         |
|---------------------|---------|---------|---------|---------|---------|---------|
| $\sigma$            | 0.0485  | -0.0107 | -0.2491 | -0.0569 | 0.0280  | -5.1234 |
| $x^2$               | 0.3653  | 0.0178  | 9.1423  | 0.4964  | 0.1234  | 2.8874  |
| DMC + Butyl Acetate |         |         |         |         |         |         |
| 303.15K             |         |         |         |         |         |         |
| $\sigma$            | -0.5859 | -0.5804 | -0.5842 | -0.6214 | -0.7117 | -4.9773 |
| $x^2$               | 46.1345 | 45.3527 | 45.8949 | 51.4164 | 65.2205 | 2.7251  |
| 308.15K             |         |         |         |         |         |         |
| $\sigma$            | -0.6949 | -0.6925 | -0.6944 | -0.7292 | -0.7896 | -5.8268 |
| $x^2$               | 62.6754 | 62.2863 | 62.5892 | 68.4422 | 78.4277 | 3.7347  |
| 313.15K             |         |         |         |         |         |         |
| $\sigma$            | -0.7998 | -0.7971 | -0.7992 | -0.8343 | -0.8589 | -6.6262 |
| $x^2$               | 80.9863 | 80.4855 | 80.8651 | 87.3650 | 91.5667 | 4.8298  |
| 318.15K             |         |         |         |         |         |         |
| $\sigma$            | 0.0485  | -0.0107 | -0.2491 | -0.0569 | 0.0280  | -7.1010 |
| $x^2$               | 0.3653  | 0.0178  | 9.1423  | 0.4964  | 0.1234  | 5.5467  |

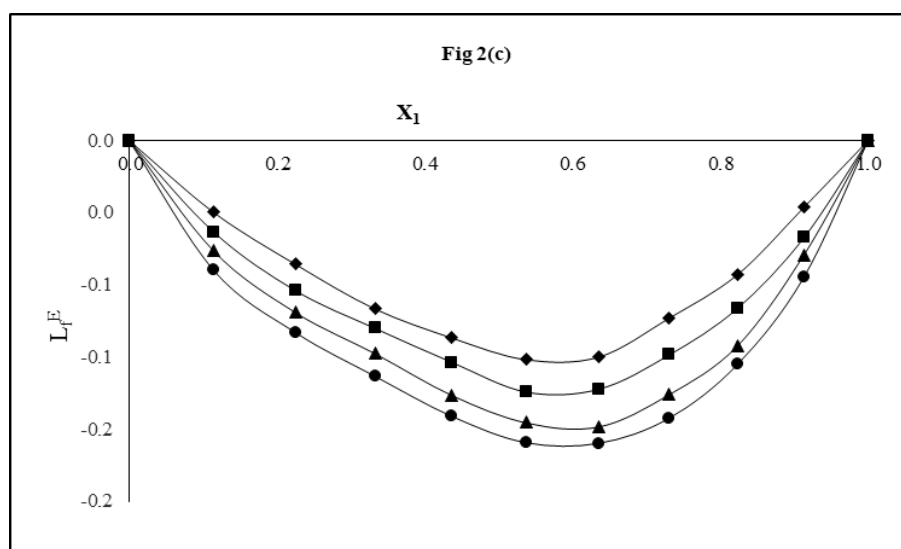
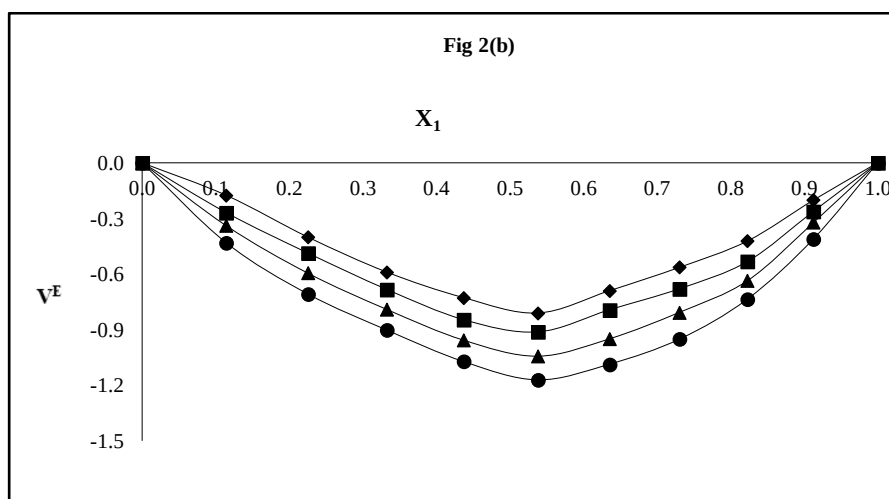
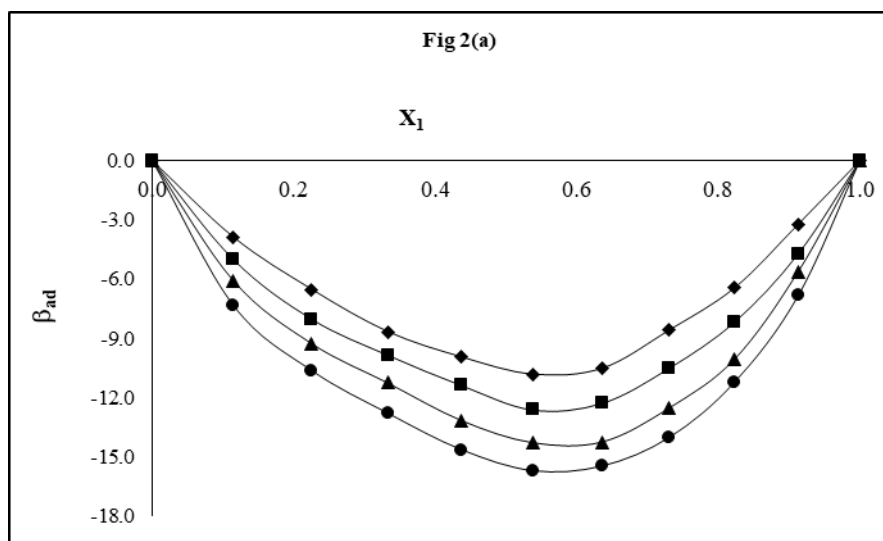
The assumption for the establishment of an ideal mixing relation is that the specific heat ratios of ideal mixtures and volumes are equal. Again, no molecular interactions are taken into consideration. Similarly, the CFT assumes that the molecules are genuine, non-elastic entities, which is not the case. However, when two liquids are mixed, their molecules interact due to the presence of numerous types of forces such as dispersion forces, charge transfer, hydrogen bonding, dipole-dipole, and dipole-induced dipole interactions. Thus, the observed departure of predicted velocity values from practical values indicates that a molecular interaction is occurring between dissimilar molecules in the liquid mixture.

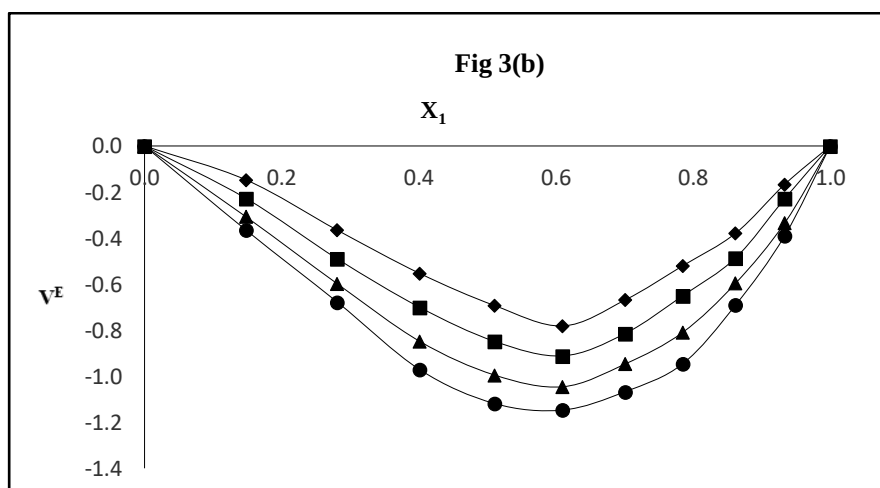
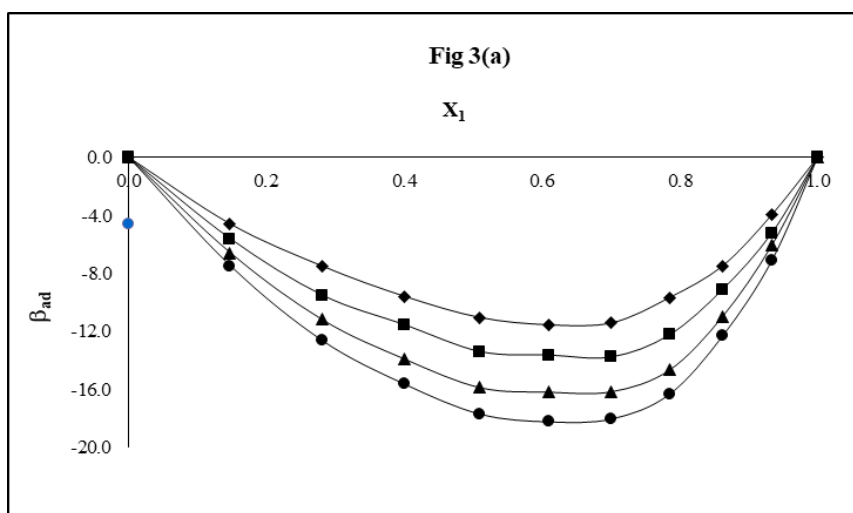
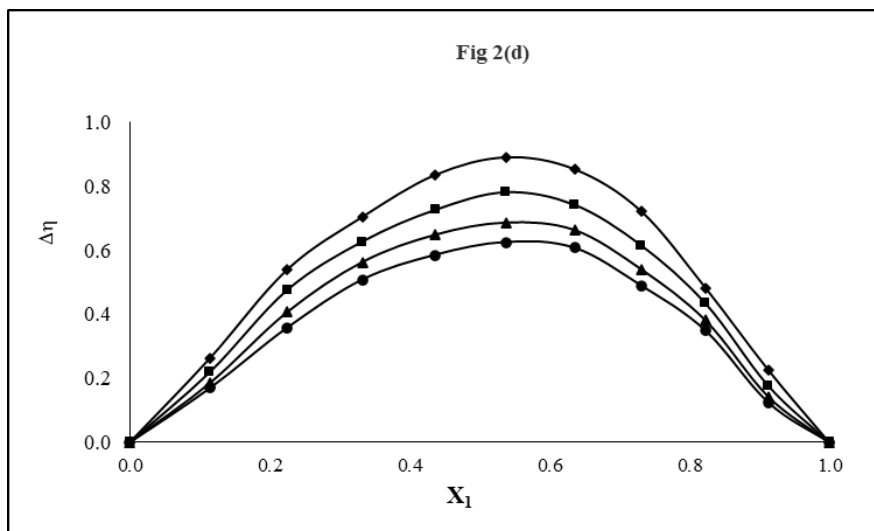
## VI. Conclusion

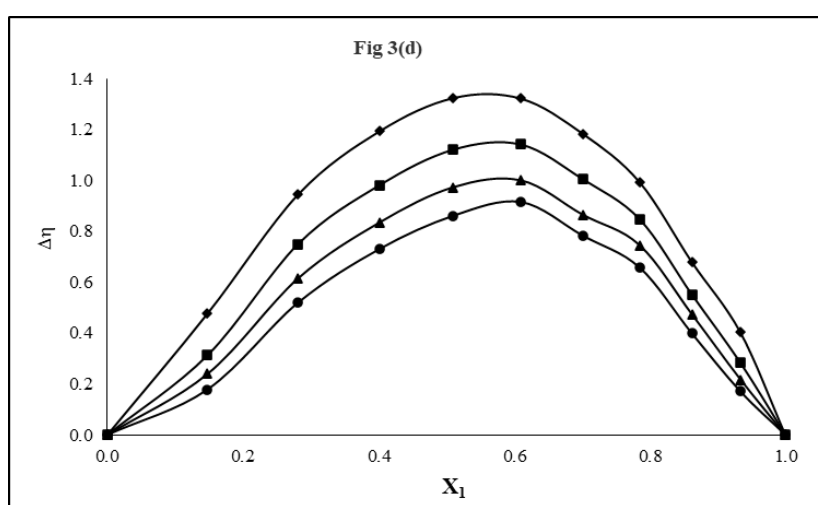
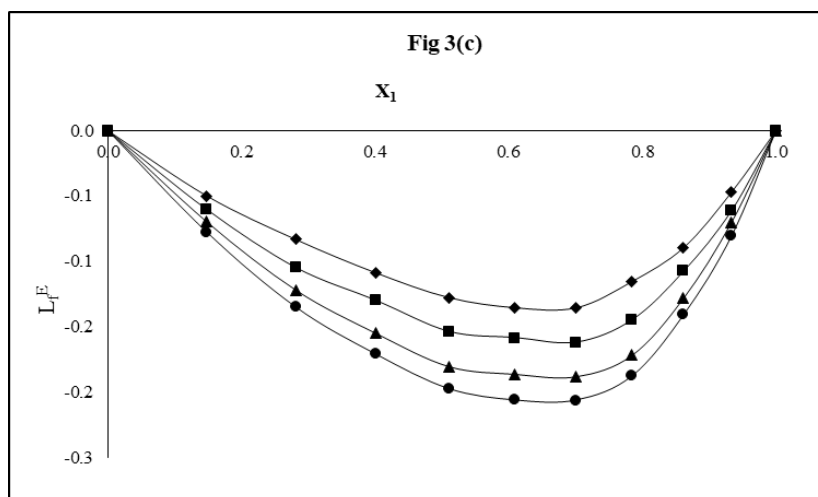
Density,  $\rho$ , and sound speed experimental data are shown, for DMC+MA, +EA, and EA mixes over the whole molefraction range at all studies temperatures  $T = (303.15 - 318.15)$  K. Over the whole composition range, excess metrics such as  $VE$ ,  $\Delta\beta_{ad}$ ,  $LfE$  and  $\Delta\eta$  were assessed. The results showed that there were intermolecular interactions between DMC and acetate molecules because of their strong hydrogen bonding. The DMC - acetate interactions in these combinations are in the following sequence, according to the magnitudes of the excess properties:  $MA > EA > BA$ .











\*\*\* Followed the same for indication different temperatures in all graphs

—●— 303.15K —■— 308.15K —▲— 313.15K —●— 318.15K

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